Principal Investigator Microgravity Services

International Space Station

PIMS Acceleration Data File Description Document

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NASA Glenn Research Center
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Revision	Effective Date	Description
Baseline	February, 2002	Baseline Release

Acronyms and Abbreviations

AOS	Acquisition of Signal
EE	Electronics Enclosure
GRC	Glenn Research Center
GSE	Ground Support Equipment
HiRAP	High Resolution Accelerometer Package
HOSC	Huntsville Operations Support Center
ICU	Interim Control Unit
ISS	International Space Station
LOS	Loss of Signal
MAMS	Microgravity Acceleration Measurement System
MCOR	Medium-rate Communications Outage Recorder
MEP	Microgravity Environment Program
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
OARE	Orbital Acceleration Research Experiment
OBPR	Office of Biological and Physical Research
OSS	OARE Sensor Subsystem
PAD	PIMS Acceleration Data
PCS	Portable Computer System
PI	Principal Investigator
PIMS	Principal Investigator Microgravity Services
RTS	Remote Triaxial Sensor System
SAMS-II	Space Acceleration Measurement System-II
SE	Sensor Enclosure
SSA	Space Station Analysis
TMF	Trimmean Filter
TSC	Telescience Support Center
UDP	User Datagram Protocol
XML	Extensible Markup Language

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1 Introduction

The NASA Glenn Research Center (GRC) Principal Investigator Microgravity Services (PIMS) project supports NASA's Microgravity Research Division Principal Investigators (PI's) by providing acceleration data analysis and interpretation for a variety of microgravity carriers including the International Space Station (ISS), the Space Shuttle, the Russian Mir Space Station, parabolic aircraft, sounding rockets, and drop towers. The PIMS project is funded by the NASA Headquarters Office of Biological and Physical Research (OBPR) and is part of the NASA Glenn Research Center's Microgravity Environment Program (MEP), which integrates the analysis and interpretation component of PIMS with the various NASA sponsored acceleration measurement systems. For the ISS, these acceleration measurement systems include the Space Acceleration Measurement System-II (SAMS-II) and the Microgravity Acceleration Measurement System (MAMS).

During ISS operations, the PIMS project is responsible for receiving, processing, displaying, distributing, and archiving the acceleration data from SAMS-II and MAMS. These tasks are accomplished by utilizing various ISS resources and by utilizing custom software components developed by PIMS. Detailed capabilities of the PIMS custom software components related to PI support are provided in PIMS-ISS-001 [1].

2 Background and Scope

This document is intended as a reference document to describe the PIMS Acceleration Data (PAD) file format employed by the PIMS project to archive the acceleration data from the SAMS-II and MAMS ISS payloads and the Ground Support Equipment (GSE) telemetry packet data required by PIMS to support offline analysis of the MAMS data. Another primary objective of this document is to educate developers of future ISS acceleration measurement hardware on the details of the PAD file format and its associated directory hierarchy. The ultimate goal of this education process is to have such future ISS acceleration measurement systems adopt the PAD format and directory hierarchy utilized by PIMS for the SAMS-II and MAMS acceleration measurement systems for use with their own acceleration measurement system. In this way, all acceleration data obtained from the ISS would be archived in an identical format, thereby allowing microgravity PI's straightforward access to ISS acceleration data, regardless of the location of their experiment or the acceleration measurement system supporting their experiment.

2.1 Acceleration Measurement System Description

The overall microgravity acceleration environment consists of two distinct regimes: the quasi-steady environment and the vibratory/transient environment. Each segment of the overall microgravity environment has unique measurement requirements that necessitate the development of multiple acceleration measurement systems. The SAMS-II and MAMS acceleration measurement systems are briefly described here. Reference [2] provides further explanation of the two acceleration regimes.

2.1.1 MAMS

The MAMS system contains two acceleration measurement systems called MAMS Orbital Acceleration Research Experiment (OARE) Sensor Subsystem (OSS) and MAMS High Resolution Accelerometer Package (HiRAP), each with a distinct measurement objective. The purpose of the MAMS OSS data is to measure the quasi-steady accelerations on the ISS. MAMS OSS data are obtained at a rate of 10 samples per second and are low-pass filtered with a cutoff frequency of 1 Hz. Each MAMS OSS data packet contains 16 seconds of MAMS OSS acceleration data and is transmitted in real-time at a rate of one data packet every 16 seconds. MAMS has the capability to store 25.6 hours of MAMS OSS data on board. Activated at MAMS power up or via ground command, this on board storage capability allows capturing of critical quasi-steady acceleration events for later downlink. These stored acceleration data can be transmitted to the ground at a ground commanded rate between 20 and 200 kbps.

The MAMS HiRAP data are obtained at a fixed rate of 1000 samples per second and low pass filtered with a cutoff frequency of 100 Hz. The purpose of the MAMS HiRAP data is to measure the vibratory and transient accelerations on the ISS. Each MAMS HiRAP data packet contains 192 acceleration readings and is transmitted at a rate of one data packet every 0.192 seconds. MAMS does not have any capability to store MAMS HiRAP data on board.

2.1.2 SAMS-II

The SAMS-II system consists of two primary components, distributed as required throughout the ISS to measure the vibratory/transient acceleration environment. The Interim Control Unit (ICU) is a Portable Computer System (PCS) laptop configured to support the SAMS-II system. The ICU serves as a collection point for all SAMS-II acceleration data and all SAMS-II housekeeping data. Any commands intended for the SAMS-II and its components are routed through the ICU. The second component is called the Remote Triaxial Sensor Subsystem (RTS) and consists of an Electronics Enclosure (EE) and up to two Sensor Enclosures (SE). The RTS is located throughout the ISS to provide a distributed, localized measurement of the vibratory/transient microgravity acceleration environment. The SE contains the actual accelerometers and transmits its acceleration data to the EE and subsequently to the ICU for downlink to the ground.

Each SAMS sensor can be commanded to measure and downlink acceleration data at one of five sampling rates, with five corresponding cutoff frequencies. Since the SAMS sampling rate can be varied, the number of readings per packet and the number of packets per second varies as a function of the SAMS sampling rate. Table 1 illustrates the relationship amongst sampling rate, cutoff frequency, acceleration readings per packet, and acceleration data packets per second for the SAMS sensors.

Table 1 - SAMS Sampling Rates

Sampling Rate	Cutoff Frequency	Readings Per Packet	Packets Per Second
62.5	25	31 or 32	2
125	50	62or 63	2
250	100	74 or 51	4
500	200	74 or 28	8
1000	400	74 or 56	14

2.2 Space Station Analysis Coordinate System

Another important consideration is the adoption of a coordinate system for presentation of the acceleration data. Since the sensor heads themselves can be oriented in arbitrary, non-orthogonal orientations relative to each other, comparison of acceleration data between various accelerometers is difficult without first transforming that data into a common coordinate system. For this purpose, PIMS has selected the Space Station Analysis (SSA) coordinate system as the common coordinate system. Figure 1 shows the SSA coordinate system relative to the ISS configuration at flight 6A (April, 2001) and illustrates the relationship between the MAMS OSS, the MAMS HiRAP, and the SSA coordinate systems. MAMS is physically located within the United States laboratory, Destiny.

2.3 AOS and LOS Considerations

Communication from the ISS is not continuous. A time interval where real time data downlink is available is referred to as an Acquisition of Signal (AOS) interval. Similarly, the lack of real time data downlink availability is referred to as a Loss of Signal (LOS) interval. Prior to generating any acceleration data archive, both SAMS and MAMS acceleration data must have AOS data and LOS data merged. LOS data is stored on board the ISS by the Medium-rate Communication Outage Recorder (MCOR). Both SAMS and MAMS will measure and transmit acceleration data continuously throughout a given increment. Consequently, real time acceleration data are available on the ground during AOS periods and acceleration data are stored on the MCOR during LOS periods for eventual downlink.

When acceleration data are transmitted to the ground, either real time data downlink or data transmitted from a dump of the MCOR memory, data packets are routed from Marshall Space Flight Center (MSFC) to the GRC Telescience Support Center (TSC) where the PIMS GSE writes each received packet into a database table dedicated to each accelerometer supported by

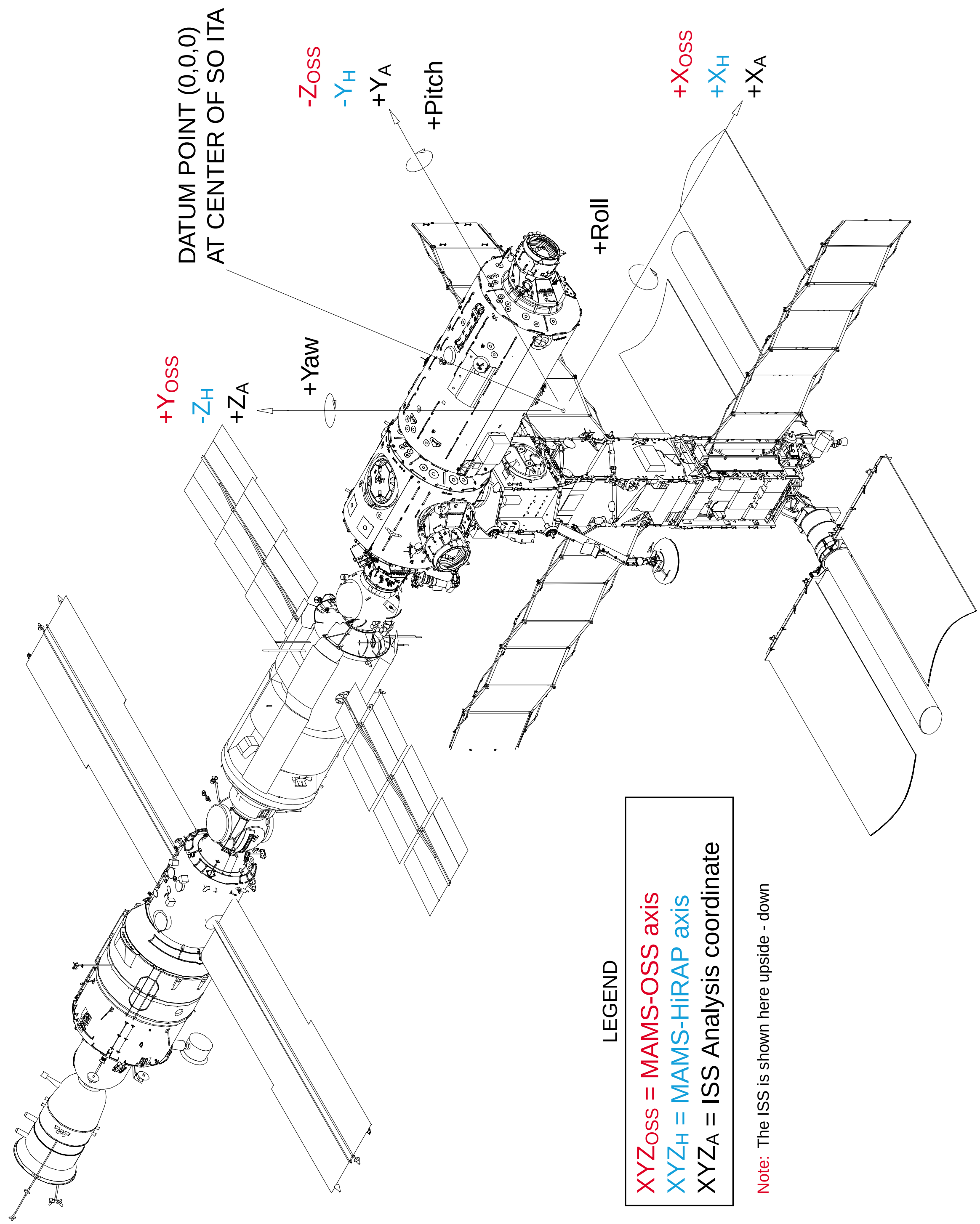

Figure 1 - Space Station Analysis Coordinate System

PIMS. Therefore, a separate database table exists for MAMS OSS, MAMS HiRAP, and the five SAMS sensors. The primary function of the database tables is to automatically merge AOS and LOS data packets for each accelerometer. The merging of the AOS and LOS streams is made possible by examining the timestamp that is transmitted as part of each acceleration data packet received by SAMS or MAMS. As there exists overlap between the AOS and LOS acceleration data packets received, each sensor's dedicated database table overwrites any redundant data packets by examining these timestamps and the packets themselves, resulting in a table containing a contiguous set of acceleration data packets that is ready for the archival process.

3 PAD File Description and Directory Hierarchy

A discussion of the PAD directory hierarchy and PAD file format is provided at this time. Regardless of the acceleration data type, each acceleration data archive will actually consist of two files. In general, the first file (binary format) is referred to as the data file and contains the acceleration data itself, consisting of four columns in the form of time, x-acceleration, y-acceleration, and z-acceleration. The second file (Extensible Markup Language (XML) format) is referred to as the header file and contains ancillary data that describes the circumstances under which the data were obtained. The binary format data files are stored in little endian 32-bit IEEE floating point format. The MAMS raw acceleration data contains two additional columns in addition to the acceleration data which are the OSS base temperature and the OSS status bytes necessary for determining bias activity from the raw data stream. Each of the current acceleration data file types is described briefly in appendix A.

Also included in this section is an explanation of what constitutes a file break or file closure. The nomenclature for detecting what caused a file break is in section 3.1.1. A file break can occur for one of three reasons. The first reason is based on the archival software detecting a time gap when generating the PAD file. A time gap can occur for a couple of reasons. The primary cause of time gaps results from the fact that data packets are transmitted from MSFC to the GRC TSC via User Datagram Protocol (UDP); UDP does not guarantee successful delivery of each data packet. If the network transmission loses a data packet, the resultant time gap closes the current file and opens a new file. This results in the file name marked as not appendable (see section 3.1.1). Time gaps can also result from operational problems with the MCOR. If the MCOR does not successfully record data packets during an LOS interval, those data packets may be permanently lost and would therefore result in a time gap when the data archives are generated.

A second reason is based on the time period covered by a given file. When the PAD archival software is started, the user provides a maximum file size in time for the particular acceleration data type. Typically for SAMS and HiRAP data, the file sizes are limited to 10 minutes in duration. Because of the lower sampling rate, the file sizes for MAMS OSS data are typically on the order of hours. If contiguous data are received for the maximum file size specified, the specified, the current file is closed and a new file is opened. This results in the file name marked as appendable (see section 3.1.1).

The third reason is when one of the ancillary parameters described in section 3.2.2 changes value. The purpose of the ancillary data is to describe each data point contained in the associated binary data file. Therefore, when an ancillary data parameter changes value, it is necessary to close the existing data file and open a new file reflecting the change in the ancillary data. This results in the file name marked as not appendable (see section 3.1.1).

3.1 Directory Hierarchy for Data Archives

The directory structure for the data archives is based on the time the data were obtained and processed. Figure 2 illustrates the various levels of the directory structure, starting with the year, month, and day designations. Each individual sensor type as described in section 2.1 will have its own branch from the basic time based structure.

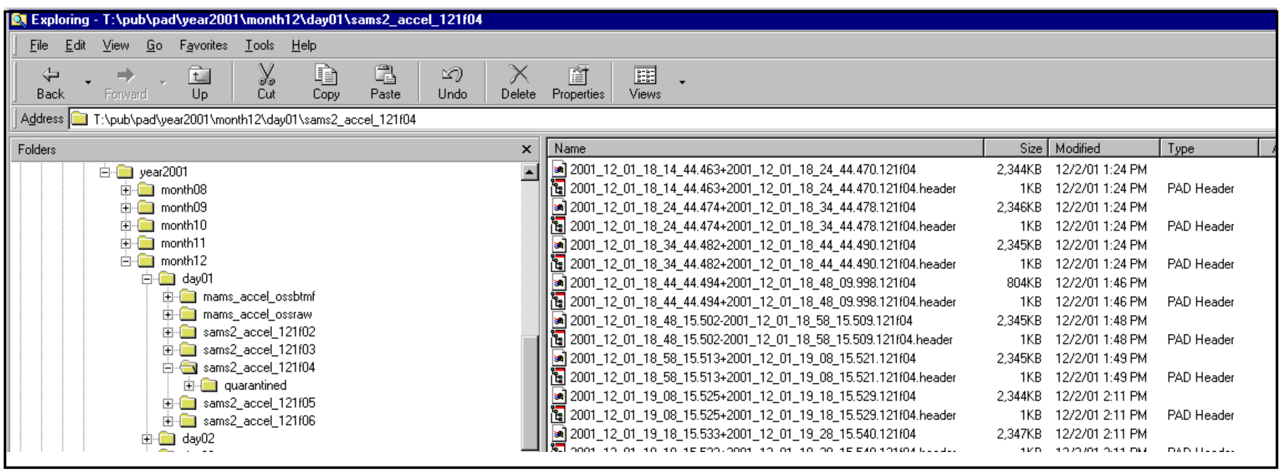

Figure 2 - PAD File Directory Structure

3.1.1 Filename Description

The filename convention for the data archives is described below. The XML header file consists of the same file name convention with a ".header" appended to the end of the base filename.

filename: `YYYY_MM_DD_hh_mm_ss.sss±YYYY_MM_DD_hh_mm_ss.sss.<SensorID>`

fields: start time isAppendable stop time . sensor

The fields are defined as follows:

start time: GMT for timestamp of first record in the data file
isAppendable: "+" if this data file is appendable to previous; otherwise "–"
stop time: GMT for timestamp of last record in the data file
sensor: sensor ID

The naming convention for the directory for each of the data types available are described in Table 2. The isAppendable designation means the data from consecutive files are truly consecutive in time with no missing acceleration readings.

Table 2 - Data Type and Sensor ID

Data Type	Data Description	Directory Name
MAMS OSS raw data	10 sample per second OSS data	mams_accel_ossraw
MAMS OSS best available trimmean filter (TMF) data	OSS data filtered to one data point every 16 seconds	mams_accel_ossbtmf
MAMS GSE data	ISS body rates and body angles data necessary to mathematically map OSS data to alternate locations	iss_rad_radgse
MAMS OSS final bias data	Bias data obtained from the OSS sensor	mams_accel_ossfbias
MAMS HiRAP data	1000 sample per second HiRAP data	mams_accel_hirap
SAMS-II data	yyy sample per second SAMS-II data, where yyy=sampling rate of a particular SAMS-II sensor	sams2_accel_121xxx, where xxx=serial number of a given SAMS-II sensor

Again, data gaps and changes in the ancillary data contained in the header file trigger creating a new file, the first of which will have **isAppendable** set to "–". With this convention, a series of files that constitute a contiguous slice of data will have **isAppendable** set to "–" in the first file of the series and a "+" in the remaining files in the series.

3.2 PIMS Acceleration Data (PAD) File Format

The details of the PAD header files and binary files are provided below. Again, the PAD file format exists in file pairs.

3.2.1 Binary File Format

The binary format data files are stored in little endian 32-bit IEEE floating point format. Each of the current acceleration data binary file types is described briefly in appendix A.

3.2.2 Description of Header File Ancillary Data Parameters

The current set of ancillary data parameters included in each archive file is described in the sections that follow. Each ancillary parameter may not be applicable to a particular sensor for a variety of reasons. Some examples of this are supplied in the following sections. Table 3 summarizes the relationship between ancillary data parameter and acceleration measurement system. However, even where the ancillary parameter does not apply, a dummy value is supplied in the ancillary file for consistency between each sensor. An example header file is described in section 3.2.3.

Table 3 - Ancillary Data Parameters and Acceleration Measurement Systems

Ancillary Parameter	Parameter Applicable to SAMS	Parameter Applicable to MAMS HiRAP	Parameter Applicable to MAMS OSS
Time Zero	YES	YES	YES
Sampling Rate	YES	YES	YES
Cutoff Frequency	YES	YES	YES
Sensor ID	YES	YES	YES
Gain	YES	NO	NO
Data Quality Measure	YES	YES	YES
Bias Coefficients	YES	YES	NO
Scale Factor	YES	YES	YES
Station Configuration	YES	YES	YES
Sensor Coordinate System	YES	YES	YES
Data Coordinate System	YES	YES	YES
g Data Format	YES	YES	YES

3.2.2.1 Time Zero

The TimeZero parameter contains the GMT time information for the first acceleration data point contained in the associated binary data file. The time information is stored in the form

YYYY_MM_DD_HH_MM_SS.SSS

where YYYY=year, MM=month, and so on.

3.2.2.2 Sampling Rate

Sampling rate is the raw number of samples obtained per second. Each acceleration data point contained in the associated binary data file was obtained at the provided sampling rate.

3.2.2.3 Cutoff Frequency

The cutoff frequency is the highest frequency passed through the data acquisition low pass filter. For the SAMS acceleration data, the relationship between sampling rate (f_s) and cutoff frequency (f_c) is defined as $f_s = f_c * 2.5$. The use of the data acquisition low pass filter is necessary to eliminate or minimize the potential effects of aliasing that may be introduced in the digitization of the original analog acceleration data signal.

3.2.2.4 Sensor ID

The head ID is a name used to uniquely distinguish one accelerometer's data from another accelerometer. The initial deployment of SAMS accelerometers on the ISS consists of five accelerometers named uniquely by their serial numbers. MAMS HiRAP data is one of a kind and its head ID is simply 'hirap'.

3.2.2.5 Gain

The gain is a multiplier (factor of 10) that can be set for the SAMS data to improve the measurement resolution with a tradeoff in loss of dynamic range. For nominal ISS operations, the SAMS gain is fixed and the gain value is typically only altered during ground testing of the SAMS unit. Nonetheless, it is provided with the header for completeness. Neither MAMS OSS nor MAMS HiRAP makes use of the gain feature.

3.2.2.6 Data Quality Measure

The data quality measure is a text input provided by PIMS data analysts to describe any problems that may have been experienced with a particular data set during data acquisition or processing.

3.2.2.7 Bias Coefficients

Bias coefficients are the numbers utilized by SAMS on board the ISS to convert the measured acceleration signal from counts to units of acceleration. MAMS OSS data performs on board bias calibrations to obtain these bias numbers.

3.2.2.8 Scale Factor Data

Scale factor data are similar to bias coefficients and are used to convert the measured acceleration signal from counts to units of acceleration.

3.2.2.9 Station Configuration

The station configuration parameter is a text input that describes the time period when the data were obtained. The format used for this parameter is typically Increment: X, Flight: Y.

3.2.2.10 Sensor Coordinate System

The sensor coordinate system parameter contains several pieces of information in its subfields. In general, these subfields describe location and orientation information for the sensor itself. Its intent is to describe the coordinate system information about the sensor. The subfields are defined below.

3.2.2.10.1 Name

The name parameter contains a unique name used to describe the "as measured" sensor coordinate system. The name typically equals the sensor ID and is used when describing "sensor coordinates."

3.2.2.10.2 Roll, Pitch, Yaw Values

The roll, pitch, and yaw values are the rotation angles which describe the sensor orientation with respect to the SSA coordinate system which is used as a reference coordinate system by PIMS. The rotation angles are for a Yaw-Pitch-Roll sequence of rotations. Details relative to coordinate system transformation are provided in Appendix B.

3.2.2.10.3 X, Y, Z Location Values

The X, Y, Z location values are the physical distances in inches from the origin of the SSA coordinate system to the sensors current physical location.

3.2.2.10.4 Comment

The comment field contains 2 values in text form to describe the physical location of the sensor. The 2 values are the ISS location format (see Reference [3]), and a descriptive string, usually describing the associated rack, and the location within a rack.

3.2.2.10.5 Time

The time field contains a value in text form that describes when the coordinate system was created. The time and name fields combined make up a unique identifier for a particular coordinate system. This is used to keep track of revisions in the PIMS coordinate system database. This time information is stored in the form:

YYYY_MM_DD_HH_MM_SS.SSS

3.2.2.11 Data Coordinate System

The data coordinate system parameter contains several pieces of information in its subfields. In general, these subfields provide information required for transforming the acceleration data from one coordinate system to another. Its intent is to describe coordinate system information about the data in the accompanying data file; this may differ from sensor alignment. The subfields are defined below.

3.2.2.11.1 Name

The name parameter contains a unique name used to describe the coordinate system of the data stored in the associated binary data file.

3.2.2.11.2 Roll, Pitch, Yaw Values

The roll, pitch, and yaw values are the rotation angles which describe the orientation of the coordinate system of the acceleration data with respect to the SSA coordinate system used as a reference coordinate system by PIMS. Details relative to coordinate system transformation are provided in Appendix B.

3.2.2.11.3 X,Y, Z Location Values

The X, Y, Z location values are the physical distances in inches from the origin of the SSA coordinate system to the sensors current physical location.

3.2.2.11.4 Comment

The comment field contains 2 values in text form to describe the physical location of the sensor. The 2 values are the ISS location format (see Reference [3]), and a descriptive string, usually describing the associated rack, and the location within a rack.

3.2.2.11.5 Time

The time field contains a value in text form that describes when the coordinate system was created. The time and name fields combined make up a unique identifier for a particular coordinate system. This is used to keep track of revisions in the PIMS coordinate system database. The time information is stored in the form:

YYYY_MM_DD_HH_MM_SS.SSS

3.2.2.12 g Data Format

The g data format parameter describes the storage format for the acceleration data stored in the binary data file. For SAMS and MAMS data, this format is always binary 32-bit IEEE float little endian.

3.2.3 Example Header Data File

The following text is an actual SAMS header file obtained during ISS operations. Each item in this sample header file is explained in detail below in Table 4.

Sample SAMS Header File Specifically Described in Table 4


```
<?xml version="1.0" encoding="US-ASCII"?>
<sams2_accel>
<SensorID>121f05</SensorID>
<TimeZero>2001_12_08_00_03_10.583</TimeZero>
<Gain>10.0</Gain>
<SampleRate>62.5</SampleRate>
<CutoffFreq>25.0</CutoffFreq>
<GData format="binary 32 bit IEEE float little endian"
file="2001_12_08_00_03_10.583+2001_12_08_00_13_10.574.121f05"/>
<BiasCoeff x="1.23" y="4.46" z="7.89"/>
<SensorCoordinateSystem name="121f05" r="90.0" p="0.0" w="90.0"
x="185.17" y="38.55" z="149.93" comment="LAB1O1, ER2, Upper Z Panel"
time="2001_05_17_15_14_40.000"/>
<DataCoordinateSystem name="121f05" r="90.0" p="0.0" w="90.0"
x="185.17" y="38.55" z="149.93" comment="LAB1O1, ER2, Upper Z Panel"
time="2001_05_17_15_14_40.000"/>
<DataQualityMeasure>temperature+gain+axial-mis-alignment,
Valid</DataQualityMeasure>
<ISSConfiguration>Increment: 3, Flight: 7A.1</ISSConfiguration>
<ScaleFactor x="1.0" y="1.0" z="1.0"/>
</sams2_accel>
```

Table 4 - Detailed Explanation of Header File Parameters

Parameter	Detailed Explanation
SensorID	The sensor is SAMS sensor serial number 121f05
TimeZero	The first data point in this file has a time stamp of 12/18/2001 00:03:10.583
Gain	Each data point in the associated binary data file was obtained using a gain of 10.
SampleRate	Each data point in the associated binary data file was obtained at a sample rate of 62.5Hz.
CutoffFreq	Each data point in the associated binary data file was obtained at a cutoff frequency of 25 Hz.
Gdata format	The associated binary data file is written as binary 32 bit IEEE float little endian. The associated binary data file name is "2001_12_08_00_03_10.583+2001_12_08_00_13_10.574.121f05".
BiasCoeff	These are dummy bias coefficients set to values of x="1.23" y="4.46" z="7.89". The acceleration data are sent to the ground in units of g's.
SensorCoordinateSystem	The sensor coordinate system name for this sensor is "121f05". The conversion angles to rotate to this coordinate system from the SSA coordinate system are r="90.0" p="0.0" w="90.0". The location (in inches) of the sensor relative to the SSA coordinate system origin is x="185.17" y="38.55" z="149.93". The sensor is location in the USLab, overhead bay location #1, on the upper Z panel above ER#2.
DataCoordinateSystem	The associated binary data file is written in the coordinate system "121f05" (sensor coordinates). See SensorCoordinateSystem for remaining details.
DataQuality Measure	Data in the associated binary data file have been compensated for "temperature+gain+axial-mis-alignment, Valid" and the data are valid.
ISSConfiguration	The data were obtained during ISS increment 3, flight 7A.1 phase.
ScaleFactor	Unity scale factors were applied to the data.

4 File Break Examples

Three examples of file breaks are provided in this section. The examples selected are representative of the majority of the types of file breaks observed thus far in ISS operations, namely time gap, sample rate change, and ISS configuration changes (increment or ISS flight bourndaries). Each example includes a screen snap of the basic directory structure, including the specific file names that result from the file break. Following the directory structure are the contents of the headers files, both prior to and after the observed break in data continuity.

4.1 Time Gap Example

The left portion of the time gap example in Figure 3 shows the basic directory structure for data accumulated during the year2001, with ‘year2001’, followed by ‘month12’, ‘day01’, and ‘sams2_accel_121f04’. The right portion with the blown up section shows a file break resulting from a time gap in the acceleration data, most likely due to an unexpected LOS period. The PAD file 2001_12_01_18_44_44.494+2001_12_01_18_48_09.998.121f04 is contiguous with the previous PAD file as indicated by the ‘+’ sign in the file name. The next PAD file, 2001_12_01_18_48_15.502-2001_12_01_18_58_15.509.121f04, is not contiguous with the previous file, as indicated by the ‘-‘ sign in the filename. The time difference between the data files 2001_12_01_18_44_44.494+2001_12_01_18_48_09.998.121f04 and 2001_12_01_18_48_15.502-2001_12_01_18_58_15.509.121f04 is about 5.5 seconds. It is this time gap that causes the introduction of the ‘-‘ into the file name. The header files for this example are identical except for the differences highlighted in bold text in sections 4.1.1 and 4.1.2 below. None of these highlighted differences would cause a file break.

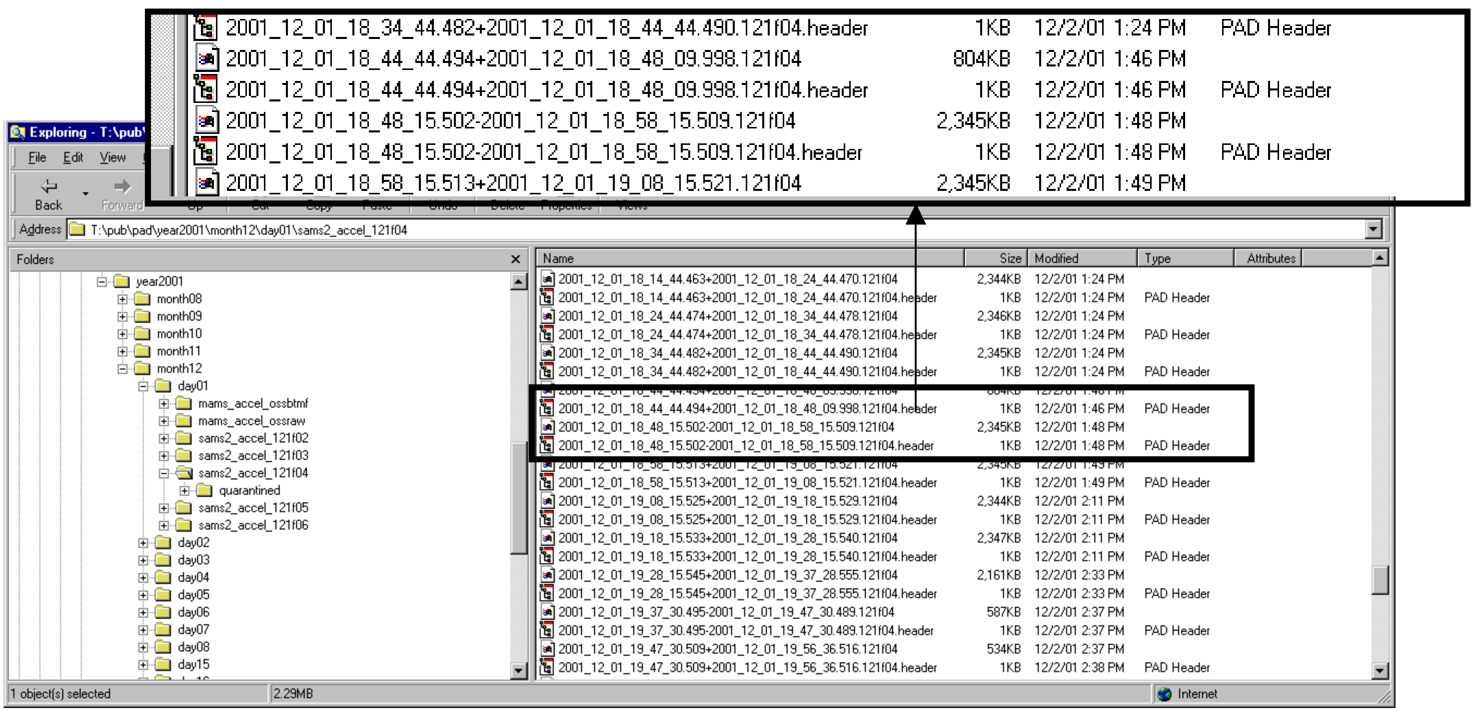

Figure 3 - Directory Structure for Time Gap Example

4.1.1 Header File for 2001_12_01_18_44_44.494+2001_12_01_18_48_09.998.121f04


```
<?xml version="1.0" encoding="US-ASCII"?>
<sams2_accel>
<SensorID>121f04</SensorID>
<TimeZero>2001_12_01_18_44_44.494</TimeZero>
<Gain>10.0</Gain>
<SampleRate>250.0</SampleRate>
<CutoffFreq>100.0</CutoffFreq>
<GData format="binary 32 bit IEEE float little endian"
file="2001_12_01_18_44_44.494+2001_12_01_18_48_09.998.121f04"/>
<BiasCoeff x="1.23" y="4.46" z="7.89"/>
<SensorCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataQualityMeasure>temperature+gain+axial-mis-alignment,
Valid</DataQualityMeasure>
<ISSConfiguration>Increment: 3, Flight: 7A.1</ISSConfiguration>
<ScaleFactor x="1.0" y="1.0" z="1.0"/>
</sams2_accel>
```


4.1.2 Header File for 2001_12_01_18_48_15.502-2001_12_01_18_58_15.509.121f04


```
<?xml version="1.0" encoding="US-ASCII"?>
<sams2_accel>
<SensorID>121f04</SensorID>
<TimeZero>2001_12_01_18_48_15.502</TimeZero>
<Gain>10.0</Gain>
<SampleRate>250.0</SampleRate>
<CutoffFreq>100.0</CutoffFreq>
<GData format="binary 32 bit IEEE float little endian"
file="2001_12_01_18_48_15.502-2001_12_01_18_58_15.509.121f04"/>
<BiasCoeff x="1.23" y="4.46" z="7.89"/>
<SensorCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataQualityMeasure>temperature+gain+axial-mis-alignment,
Valid</DataQualityMeasure>
<ISSConfiguration>Increment: 3, Flight: 7A.1</ISSConfiguration>
<ScaleFactor x="1.0" y="1.0" z="1.0"/>
</sams2_accel>
```

4.2 Sample Rate and Gain Change Example

For the sampling rate and gain change example shown in Figure 4, the left portion of the figure shows the basic directory structure for data accumulated during the year2001, with 'year2001', followed by 'month12', 'day01', and 'sams2_accel_121f04'. The right portion with the blown up section shows a file break resulting from a change in the sampling rate and the gain for SAMS sensor 121f04. The PAD file 2001_12_01_04_05_40.957+2001_12_01_04_15_03.464.121f04 is contiguous with the previous PAD file as indicated by the '+' sign in the file name. The next PAD file, 2001_12_01_04_15_15.790-2001_12_01_04_25_15.801.121f04, is not contiguous with the previous file, as indicated by the '-' sign in the filename. There is a time difference between the two data files that results from a sampling rate change. However, the fundamental cause of this particular file break is the change in sampling rate and gain and not a time gap. It is the sampling rate change and gain change that causes the introduction of the '-' into the file name. The differences between the header files for this example are highlighted in bold text in sections 4.2.1 and 4.2.2 below.

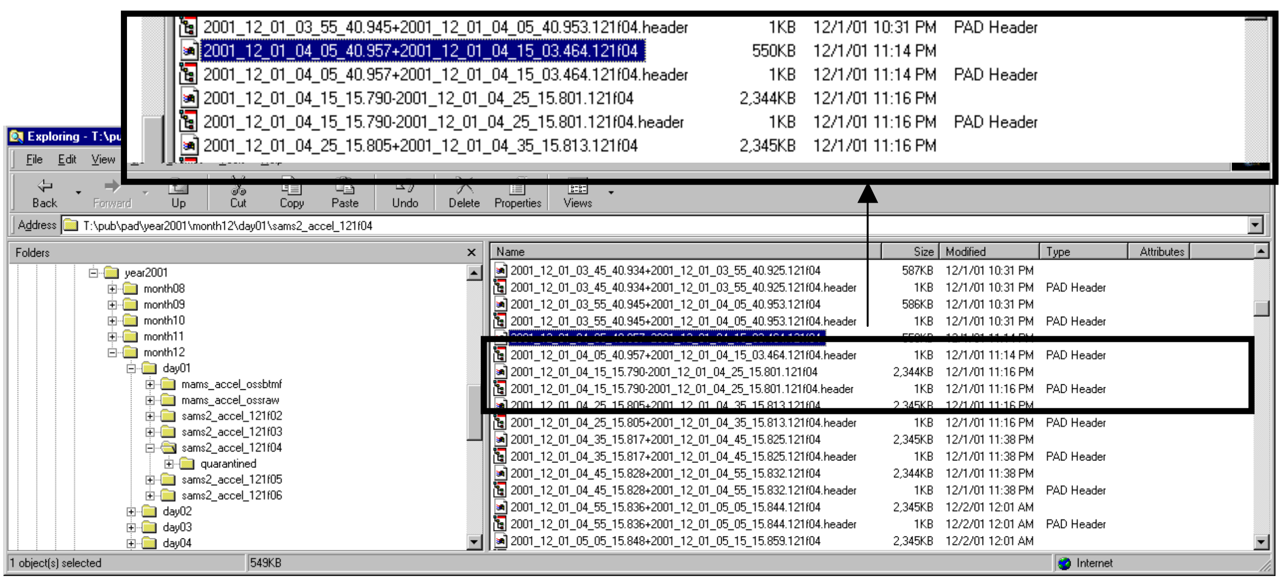

Figure 4 - Directory Structure for Sampling Rate and Gain Change Example

4.2.1 Header File for 2001_12_01_04_05_40.957+2001_12_01_04_15_03.464.121f04


```xml
<?xml version="1.0" encoding="US-ASCII"?>
<sams2_accel>
<SensorID>121f04</SensorID>
<TimeZero>2001_12_01_04_05_40.957</TimeZero>
<Gain>1.0</Gain>
<SampleRate>62.5</SampleRate>
<CutoffFreq>25.0</CutoffFreq>
<GData format="binary 32 bit IEEE float little endian"
file="2001_12_01_04_05_40.957+2001_12_01_04_15_03.464.121f04"/>
<BiasCoeff x="1.23" y="4.46" z="7.89"/>
<SensorCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataQualityMeasure>gain+axial-mis-alignment,
Valid</DataQualityMeasure>
<ISSConfiguration>Increment: 3, Flight: 7A.1</ISSConfiguration>
<ScaleFactor x="1.0" y="1.0" z="1.0"/>
</sams2_accel>
```


4.2.2 Header File for 2001_12_01_04_15_15.790-2001_12_01_04_25_15.801.121f04


```xml
<?xml version="1.0" encoding="US-ASCII"?>
<sams2_accel>
<SensorID>121f04</SensorID>
<TimeZero>2001_12_01_04_15_15.790</TimeZero>
<Gain>10.0</Gain>
<SampleRate>250.0</SampleRate>
<CutoffFreq>100.0</CutoffFreq>
<GData format="binary 32 bit IEEE float little endian"
file="2001_12_01_04_15_15.790-2001_12_01_04_25_15.801.121f04"/>
<BiasCoeff x="1.23" y="4.46" z="7.89"/>
<SensorCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataCoordinateSystem name="121f04" r="0.0" p="30.0" w="-90.0"
x="149.54" y="-40.54" z="135.25" comment="LAB1O2, ER1, Lower Z Panel"
time="2001_05_17_15_12_44.000"/>
<DataQualityMeasure>temperature+gain+axial-mis-alignment,
Valid</DataQualityMeasure>
<ISSConfiguration>Increment: 3, Flight: 7A.1</ISSConfiguration>
<ScaleFactor x="1.0" y="1.0" z="1.0"/>
</sams2_accel>
```

4.3 ISS Configuration Change Example

The left portions of the ISS configuration change examples shown in Figure 5 and Figure 6 show the basic directory structure for data accumulated during the year2001, with 'year2001', followed by 'month12', 'day01', and 'sams2_accel_121f03'. The right portions with the blown up sections show a file break resulting from a change in the ISS configuration for SAMS sensor 121f03. The PAD file 2001_12_08_20_55_38.795+2001_12_08_21_05_38.794.121f03 is contiguous with the previous PAD file as indicated by the '+' sign in the file name. This is the last PAD file for increment 3 for SAMS sensor 121f03. The first file of Figure 6, 2001_12_15_01_28_02.915-2001_12_15_01_38_02.914.121f03, is the first file of increment 4 and is not contiguous with the previous file, as indicated by the '-' sign in the filename. There is a time difference between the two data files. The cause of this particular file break is the change in ISS configuration and the time difference. The differences between the header files for this example are highlighted in bold text in sections 4.2.1 and 4.2.2 below.

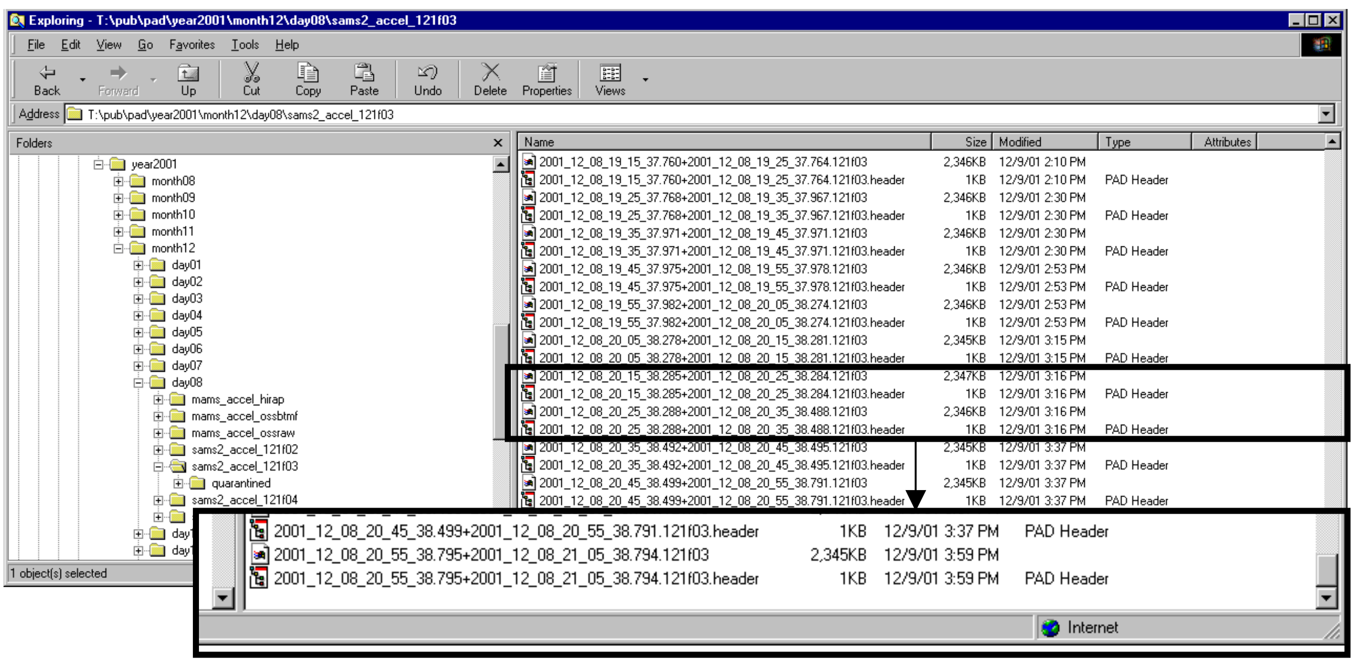

Figure 5 - ISS Configuration Change File Break Example Part 1

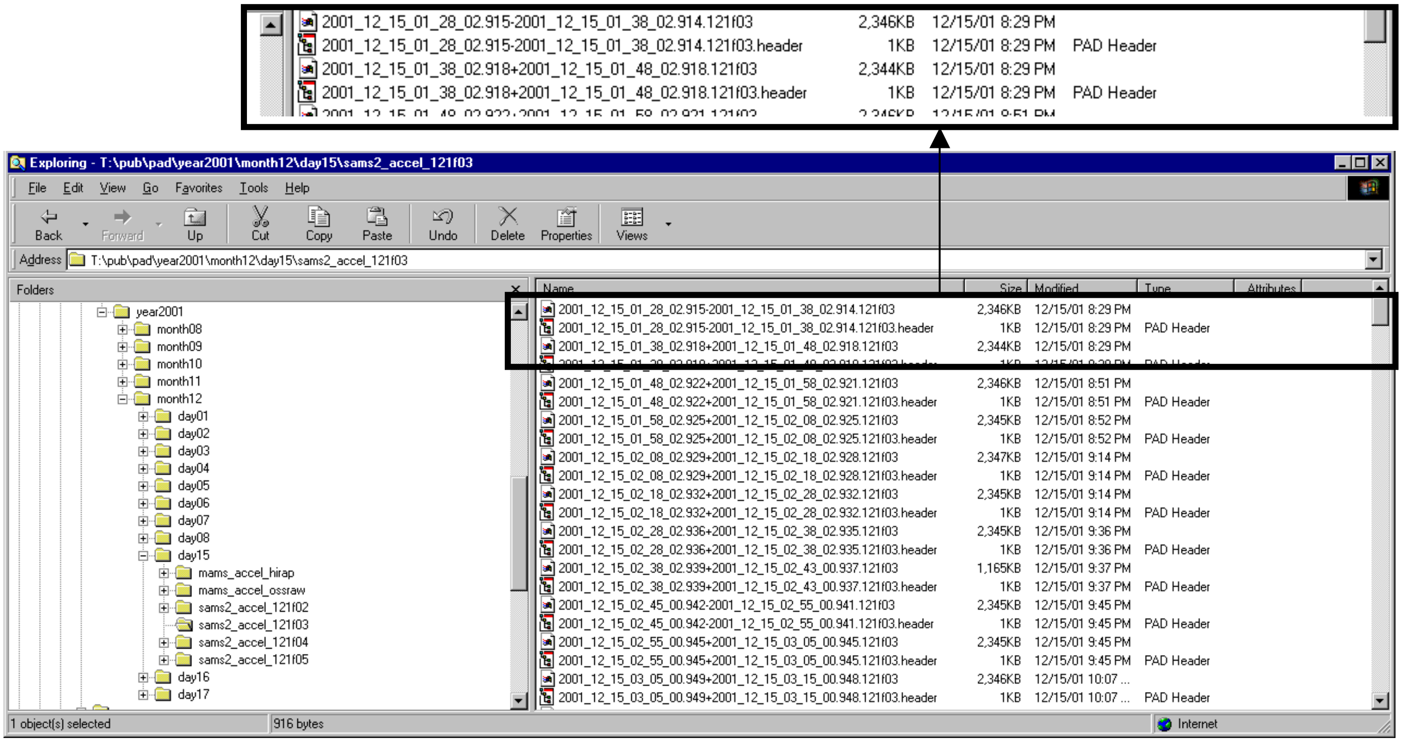

Figure 6 - ISS Configuration Change File Break Example Part 2

4.3.1 Header File for 2001_12_08_20_55_38.795+2001_12_08_21_05_38.794.121f03

```
<?xml version="1.0" encoding="US-ASCII"?>
<sams2_accel>
<SensorID>121f03</SensorID>
<TimeZero>2001_12_08_20_55_38.795</TimeZero>
<Gain>10.0</Gain>
<SampleRate>250.0</SampleRate>
<CutoffFreq>100.0</CutoffFreq>
<GData format="binary 32 bit IEEE float little endian"
file="2001_12_08_20_55_38.795+2001_12_08_21_05_38.794.121f03"/>
<BiasCoeff x="1.23" y="4.46" z="7.89"/>
<SensorCoordinateSystem name="121f03" r="0.0" p="30.0" w="-90.0"
x="191.54" y="-40.54" z="135.25" comment="LAB1O1, ER2, Lower Z Panel"
time="2001_05_17_15_11_43.000"/>
<DataCoordinateSystem name="121f03" r="0.0" p="30.0" w="-90.0"
x="191.54" y="-40.54" z="135.25" comment="LAB1O1, ER2, Lower Z Panel"
time="2001_05_17_15_11_43.000"/>
<DataQualityMeasure>temperature+gain+axial-mis-alignment,
Valid</DataQualityMeasure>
<ISSConfiguration>Increment: 3, Flight: 7A.1</ISSConfiguration>
<ScaleFactor x="1.0" y="1.0" z="1.0"/>
</sams2_accel>
```

4.3.2 Header File for 2001_12_15_01_28_02.915-2001_12_15_01_38_02.914.121f03


```
<?xml version="1.0" encoding="US-ASCII"?>
<sams2_accel>
<SensorID>121f03</SensorID>
<TimeZero>2001_12_15_01_28_02.915</TimeZero>
<Gain>10.0</Gain>
<SampleRate>250.0</SampleRate>
<CutoffFreq>100.0</CutoffFreq>
<GData format="binary 32 bit IEEE float little endian"
file="2001_12_15_01_28_02.915-2001_12_15_01_38_02.914.121f03"/>
<BiasCoeff x="1.23" y="4.46" z="7.89"/>
<SensorCoordinateSystem name="121f03" r="0.0" p="30.0" w="-90.0"
x="191.54" y="-40.54" z="135.25" comment="LAB1O1, ER2, Lower Z Panel"
time="2001_05_17_15_11_43.000"/>
<DataCoordinateSystem name="121f03" r="0.0" p="30.0" w="-90.0"
x="191.54" y="-40.54" z="135.25" comment="LAB1O1, ER2, Lower Z Panel"
time="2001_05_17_15_11_43.000"/>
<DataQualityMeasure>temperature+gain+axial-mis-alignment,
Valid</DataQualityMeasure>
<ISSConfiguration>Increment: 4, Flight: UF1</ISSConfiguration>
<ScaleFactor x="1.0" y="1.0" z="1.0"/>
</sams2_accel>
```

References

[1] K. McPherson, Software Requirements for Processing Microgravity Acceleration Data from the International Space Station, PIMS-ISS-001, Revision A, August, 2001.

[2] PIMS Brochure, http://microgravity.grc.nasa.gov/MSD/MSD_documents/PIMS_Brochure.pdf

[3] Space Station Interior and Exterior Operational Location Coding System, SSP-30575.

Appendix A – Acceleration Data File Types

A.1.Four Column Acceleration Data File

The four-column acceleration data file type is used to archive acceleration data for each SAMS sensor, the MAMS HiRAP sensor, and the MAMS OSS best available TMF data types. The output from a sample acceleration data file is provided below. Per the header files discussed previously in section 4, the binary data stored in the acceleration data files are stored in binary 32 bit IEEE float little endian format. This format is specified in the 'GData format' header file parameter. Twenty sample records from a four-column acceleration data file are provided below. To verify the proper operation of file reading software, the following result should be obtained from the first twenty records of the data file:

2001_12_01_00_05_27.462+2001_12_01_00_15_27.464.121f02

Figure A - 1 Four-Column Example

Time	X-Acceleration	Y-Acceleration	Z-Acceleration
0.00E+00	9.837032E-04	-4.740996E-04	-4.150363E-04
2.00E-03	-2.270368E-04	1.804806E-04	1.510161E-04
4.00E-03	-3.432796E-04	7.942862E-04	-1.494198E-05
6.00E-03	8.387887E-04	-3.459106E-04	-3.441011E-06
8.00E-03	1.415047E-04	-7.893521E-04	7.512448E-04
1.00E-02	-1.019951E-03	2.896064E-04	-8.919730E-05
1.20E-02	6.460590E-04	-1.200642E-04	-2.890266E-04
1.40E-02	4.568079E-04	-1.107866E-03	8.468466E-04
1.60E-02	-1.196886E-03	1.798459E-04	6.793907E-05
1.80E-02	7.237342E-04	9.244012E-04	-7.356259E-04
2.00E-02	1.297818E-03	-6.380729E-04	1.977606E-04
2.20E-02	-7.137657E-04	-2.843878E-04	4.605404E-04
2.40E-02	-4.200042E-04	1.093102E-03	-6.532240E-04
2.60E-02	1.044050E-03	-1.322112E-04	2.121586E-04
2.80E-02	-8.959807E-05	-8.211969E-04	1.130929E-03
3.00E-02	-1.082437E-03	5.247764E-04	-9.678888E-04
3.20E-02	8.361743E-04	2.773062E-04	-9.347146E-04
3.40E-02	6.122881E-04	-8.240640E-04	1.250753E-03
3.60E-02	-1.076711E-03	2.808300E-04	2.774833E-04
3.80E-02	3.359845E-04	5.769318E-04	-1.140098E-03

A.2.Six Column Acceleration Data File

The six-column acceleration data file type is used to archive acceleration data for each MAMS OSS raw data only. The output from a sample acceleration data file is provided below. Per the header files discussed previously in section 4, the binary data stored in the acceleration data files are stored in binary 32 bit IEEE float little endian format. This format is specified in the 'GData format' header file parameter. Twenty sample records from a six-column acceleration data file are provided below. To verify the proper operation of file reading software, the following result should be obtained from the first twenty records of the data file:

2001_12_01_01_00_29.547+2001_12_01_03_00_42.531.ossraw

Figure A - 2 Six-Column Example

Time	X-Acceleration	Y-Acceleration	Z-Acceleration	MAMS Temperature	MAMS Status Byte
0.000000E+00	-4.595947E-06	1.519775E-05	5.799866E-06	3.962188E+01	8.923682E+06
1.000000E-01	-5.850220E-06	9.017945E-06	1.968384E-06	3.962188E+01	8.923682E+06
2.000000E-01	-6.192017E-06	3.474426E-06	-3.753662E-07	3.962188E+01	8.923682E+06
3.000000E-01	-5.538941E-06	2.471924E-07	-1.281738E-06	3.962188E+01	8.923682E+06
4.000000E-01	-4.421997E-06	-8.148193E-07	-7.324219E-07	3.962188E+01	8.923682E+06
5.000000E-01	-3.283692E-06	-1.208496E-06	1.419067E-06	3.962188E+01	8.923682E+06
6.000000E-01	-1.971435E-06	-2.947998E-06	4.417419E-06	3.962188E+01	8.923682E+06
7.000000E-01	-1.831055E-07	-7.781982E-06	7.044983E-06	3.962188E+01	8.923682E+06
8.000000E-01	1.962280E-06	-1.624145E-05	8.427429E-06	3.962188E+01	8.923682E+06
9.000000E-01	3.738403E-06	-2.723236E-05	9.017945E-06	3.962188E+01	8.923682E+06
1.000000E+00	4.553223E-06	-3.824158E-05	1.031342E-05	3.962188E+01	8.923682E+06
1.100000E+00	4.632569E-06	-4.673309E-05	1.301880E-05	3.962188E+01	8.923682E+06
1.200000E+00	4.531860E-06	-5.131073E-05	1.582947E-05	3.962188E+01	8.923682E+06
1.300000E+00	4.891968E-06	-5.192413E-05	1.695099E-05	3.962188E+01	8.923682E+06
1.400000E+00	5.905151E-06	-4.969482E-05	1.591186E-05	3.962188E+01	8.923682E+06
1.500000E+00	7.131958E-06	-4.622040E-05	1.347198E-05	3.962188E+01	8.923682E+06
1.600000E+00	7.830810E-06	-4.235229E-05	1.016235E-05	3.962188E+01	8.923682E+06
1.700000E+00	7.562256E-06	-3.816376E-05	5.863953E-06	3.962188E+01	8.923682E+06
1.800000E+00	6.661987E-06	-3.296356E-05	1.107788E-06	3.962188E+01	8.923682E+06
1.900000E+00	5.902099E-06	-2.623901E-05	-2.705383E-06	3.962188E+01	8.923682E+06

Appendix B – PIMS ISS Coordinate System Conversion

B.1. Acceleration Data Coordinate Conversion

During the life of the Space Station, PIMS will frequently be asked to present acceleration data in a coordinate system other than that of the sensor. The purpose of this section is to provide the mathematical definitions and conventions PIMS will use when performing coordinate transformations.

PIMS maintains a coordinate system database for use in PIMS real-time and offline software that contains the information necessary to describe the location and orientation of various coordinate systems relative to the Space Station Analysis Coordinate System. Each entry for a coordinate system contains the location of the origin in SSA coordinates (x,y,z) and the Euler angles (Y, P, R) describing the orientation with respect to the SSA frame. A positive rotation follows the right hand rule. So, an observer standing at positive infinity on the axis of rotation, looking towards the origin would see a counterclockwise rotation of the other two axes.

Transformation of acceleration data from the SSA coordinate system to a NEW coordinate system is accomplished by the formulation of a transformation matrix, M.

$$M_A^{NEW} = \begin{bmatrix} \cos P \cdot \cos Y & \cos P \cdot \sin Y & -\sin P \\ \sin R \cdot \sin P \cdot \cos Y - \cos R \cdot \sin Y & \sin R \cdot \sin P \cdot \sin Y + \cos R \cdot \cos Y & \sin R \cdot \cos P \\ \cos R \cdot \sin P \cdot \cos Y + \sin R \cdot \sin Y & \cos R \cdot \sin P \cdot \sin Y - \sin R \cdot \cos Y & \cos R \cdot \cos P \end{bmatrix}^{NEW}$$

Equation B - 1

$$M_A^{NEW} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

Equation B - 2

$$\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{NEW} = M_A^{NEW} \cdot \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{A}$$

Equation B - 3

Transformation of acceleration data from the NEW coordinate system to the SSA coordinate system is accomplished by multiplying the vector by the transpose of matrix M (For orthogonal matrices, $M^T = M^{-1}$). The transpose of M, M^T, can be calculated by swapping the rows and columns as depicted in Equation B - 4.

$$M^T = M_{NEW}^{A} = \begin{bmatrix} m_{11} & m_{21} & m_{31} \\ m_{12} & m_{22} & m_{32} \\ m_{13} & m_{23} & m_{33} \end{bmatrix}$$

Equation B - 4

$$\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{A} = M^T \cdot \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{NEW}$$

Equation B - 5

In general, PIMS will transform data from SENSOR coordinate system to a NEW coordinate system. This is a four step process:

1. **The orientation of the SENSOR coordinate system is found $[YPR]_{SENSOR}$ from the coordinate system database and used to calculate the transformation matrix M,**

$$M_{A}^{SENSOR} = \begin{bmatrix} \cos P \cdot \cos Y & \cos P \cdot \sin Y & -\sin P \\ \sin R \cdot \sin P \cdot \cos Y - \cos R \cdot \sin Y & \sin R \cdot \sin P \cdot \sin Y + \cos R \cdot \cos Y & \sin R \cdot \cos P \\ \cos R \cdot \sin P \cdot \cos Y + \sin R \cdot \sin Y & \cos R \cdot \sin P \cdot \sin Y - \sin R \cdot \cos Y & \cos R \cdot \cos P \end{bmatrix}^{SENSOR}$$

Equation B - 6

$$M_{A}^{SENSOR} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

Equation B - 7

2. **Since the data is currently in SENSOR coordinates, the transpose of M is calculated.**

$$M_{SENSOR}^{A} = \begin{bmatrix} m_{11} & m_{21} & m_{31} \\ m_{12} & m_{22} & m_{32} \\ m_{13} & m_{23} & m_{33} \end{bmatrix}$$

Equation B - 8

$$\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{A} = M_{SENSOR}^{A} \cdot \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{SENSOR}$$

Equation B - 9

3. **The orientation of the NEW coordinate system is found $[YPR]_{NEW}$ from the coordinate system database and used to calculate the transformation matrix N,**

$$N_{A}^{NEW} = \begin{bmatrix} \cos P \cdot \cos Y & \cos P \cdot \sin Y & -\sin P \\ \sin R \cdot \sin P \cdot \cos Y - \cos R \cdot \sin Y & \sin R \cdot \sin P \cdot \sin Y + \cos R \cdot \cos Y & \sin R \cdot \cos P \\ \cos R \cdot \sin P \cdot \cos Y + \sin R \cdot \sin Y & \cos R \cdot \sin P \cdot \sin Y - \sin R \cdot \cos Y & \cos R \cdot \cos P \end{bmatrix}_{NEW}$$

Equation B - 10

$$\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{NEW} = N_{A}^{NEW} \cdot \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{A}$$

Equation B - 11

4. **The equivalent transformation matrix T is calculated by substitution of Equation B - 9 into Equation B - 11**

$$T_{SENSOR}^{NEW} = N_{A}^{NEW} \cdot M_{SENSOR}^{A}$$

Equation B - 12

$$\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{NEW} = T_{SENSOR}^{NEW} \cdot \begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}^{SENSOR}$$

Equation B - 13

Appendix Z – Open Work

Date Opened	Problem Description